HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1930

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Issued June, 1931

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the joint supervision of the Office of Experiment Stations, United States Department of Agriculture, and the University of Hawaii]

WALTER H. EVANS, *Acting Chief, Office of Experiment Stations, and Chief, Division of Insular Stations.*
D. L. CRAWFORD, *President, University of Hawaii.*

STATION STAFF

J. M. WESTGATE, *Director.*
L. A. HENKE, *Animal Husbandman.*
J. C. RIPPERTON, *Chemist.*
MRS. L. N. BILGER, *Research Chemist.*
W. T. POPE, *Horticulturist.*
CAREY D. MILLER, *Specialist in Nutrition.*
C. M. BICE, *Poultry Husbandman.*
H. A. WADSWORTH, *Irrigation Engineer and Collaborator in Soil Physics.*
D. W. EDWARDS, *Junior Chemist.*
JOHN CASTRO, *Plant Propagator.*
M. TAKAHASHI, *Assistant in Agronomy.*
M. MANEKI, *Assistant in Animal Husbandry.*

KONA SUBSTATION

R. K. PAHAU, *Superintendent, Kealakekua.*

MAUI SUBSTATION

H. F. WILLEY, *Superintendent, Makawao.*

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CONSOLIDATION OF STATION WORK IN HAWAII

Beginning July 1, 1929, the agricultural activities of the Federal experiment station and of the University of Hawaii were brought formally under the joint control of the United States Department of Agriculture and the university, in accordance with the following memorandum of understanding, approved by the Secretary of Agriculture and the President of the University:

MEMORANDUM OF UNDERSTANDING

Whereas, The University of Hawaii may under the Act of Congress approved May 16, 1928, receive funds appropriated by Congress for conducting experiments in agriculture; and

Whereas, The Department of Agriculture is now maintaining an agricultural experiment station in Hawaii under appropriations made by Congress; and

Whereas, The said Act of May 16, 1928, specifically provides "That the experiment station so established shall be conducted jointly and in collaboration with the existing Federal experiment station in Hawaii in enlarging and expanding the work of the said Federal experiment station on cooperative plans approved

by the Secretary of Agriculture; and the Secretary of Agriculture shall coordinate the work of the Territorial station with that of the Federal experiment station and of the United States Department of Agriculture in the Islands":

Therefore, With a view to securing economy and efficiency in the conduct of the experiment station work in the Territory of Hawaii, the Secretary of Agriculture of the United States and the President of the University of Hawaii, with the approval of the Board of Regents of said university, hereby make the following memorandum of understanding with reference to the relations between the University of Hawaii and the United States Department of Agriculture for the organization and conduct of experiment station work in agriculture in the Territory of Hawaii:

I. The University of Hawaii agrees:

(a) That instead of establishing a separate and independent station it will carry on its experimental work in association with that of the existing Federal experiment station, the joint enterprise hereafter to be known as the Hawaii Agricultural Experiment Station, conducted jointly by the United States Department of Agriculture and the University of Hawaii;

(b) That the property, equipment, and all appurtenances of the present Federal experiment station as well as that hereafter acquired by reason of appropriations made by the Congress to the Department of Agriculture for the support of said station shall be and remain the property of said Department of Agriculture;

(c) That the funds received hereafter by the University of Hawaii for experiment station work from the Congress or any other source will be expended by said university for work carried on through said Hawaii Agricultural Experiment Station;

(d) That it will cooperate with the Department of Agriculture in such agricultural experiment station work as the department is or may be authorized to conduct in the Territory of Hawaii.

II. The United States Department of Agriculture agrees:

(a) To maintain an Office of Experiment Stations which shall represent the department in its relations with the Hawaii Agricultural Experiment Station and shall have charge of the department's business connected with the administration of all funds provided by Congress for said station;

(b) That it will conduct in cooperation with the University of Hawaii through the Hawaii Agricultural Experiment Station all experimental work in agriculture which it is or may be authorized to conduct in the Territory of Hawaii;

(c) That all property, equipment, or appurtenances, purchased through funds appropriated by Congress directly to the Territory under the Act of May 16, 1928, or property, equipment, and all appurtenances acquired in any other manner shall remain the property of the University of Hawaii;

(d) That such members of the staff of the University of Hawaii as may be detailed to experiment station work may be commissioned as agents or collaborators of the United States Department of Agriculture, enabling the use of the departmental franking privilege in conducting official business.

III. The University of Hawaii and the United States Department of Agriculture mutually agree:

(a) That, subject to the approval of the President of the University of Hawaii and the Secretary of Agriculture, or their duly appointed representatives, the agricultural experiment station work shall be planned under the supervision of the director of the Hawaii experiment station, and that the approved plans shall be executed by the director of said agricultural experiment station;

(b) That all agents appointed for experiment station work by the University of Hawaii under this memorandum shall be joint representatives of the University of Hawaii and the United States Department of Agriculture, and the cooperation shall be plainly set forth in all publications or other printed matter issued and used in connection with said agricultural experiment station work by either the University of Hawaii or the United States Department of Agriculture;

(c) That the plans for the use of all congressional funds appropriated for experiment station work shall be made by the director of the Hawaii experiment station subject to the approval of the Secretary of Agriculture and the President of the University or their designated representatives, and when so approved shall be executed by the director of the station;

(d) That the headquarters of the Hawaii Agricultural Experiment Station shall be, for the present, at the present site of the Federal experiment station on Pensacola Street, but station work may be conducted at said site or on the university farm or elsewhere if the director of said station acting with the approval of the Secretary of Agriculture and President of the University, or their representatives, shall so decide.

(e) That until otherwise agreed the director of the Hawaii Agricultural Experiment Station shall be the present director of the Federal experiment station, and any succeeding director shall be chosen by the Secretary of Agriculture and the President of the University acting jointly.

IV. This memorandum shall be in effect when approved by the President of the University of Hawaii and the Secretary of Agriculture of the United States and it shall remain in effect until expressly abrogated by either of the signers or his successor in office, or amended by mutual agreement of both.

The enlarged experiment station is known as the Hawaii Agricultural Experiment Station, and is under the immediate management of the former director of the Federal station. The Federal experiment station was operated as an independent local institution from its establishment in 1901 to June 30, 1929, and agricultural investigational work at the College of Agriculture of the University of Hawaii began in 1908. The property of the two coordinated institutions is to be kept separate, but there has been a pooling of interests, personnel, and facilities, with an increase in efficiency and economy of administration and more effective cooperation with other local institutions also engaged in similar experimental work.

Under the Act of Congress, above referred to, extending the benefits of the Hatch, Adams, and Purnell Acts to Hawaii, the station received $15,000 during the year ended June 30, 1930. Beginning with the fiscal year 1931, it is to receive certain annual increments until the maximum of $90,000 provided by the three acts is reached in the fiscal year 1941.

SUMMARY OF INVESTIGATIONS

By J. M. Westgate, *Director*

Selective breeding work with over 600 different lots of pigeon peas and determination of the effect of different spacings on seed production with 85 lots of green-manuring crops constituted the chief activities of the agronomy division. Rows and plats of the more promising forage grasses were maintained for yield tests and also to furnish a convenient supply of planting material for local distribution, especially to dairy farmers. Tests of many varieties of taro, sweetpotato, edible canna, and cassava were made. The more promising of the lettuce hybrids produced by the station were planted for further elimination and selection. Numerous miscellaneous field crops and vegetables were under trial.

At the Haleakala substation, the university farm, and the Pensacola Street station similar plantings were made of pigeon peas for breeding and of green-manuring crops for seed production. Be-

cause of the higher altitude at the Haleakala substation markedly different results in growth were noted in almost every instance. Approximately 245 varieties, representing 100 different species of crops, were under trial at this substation, and improved planting material was distributed to many interested persons. The Waikea substation, Hawaii, was maintained on a self-supporting basis to determine the cost of growing sugarcane on a 62-acre area of land in the Waikea homestead tract. The Kona substation, Hawaii, was established, and preliminary cooperative experiments were undertaken, pending the erection of suitable buildings and the clearing of the land for experimental plantings.

Work in animal husbandry begun by the university was largely along the line of feeding experiments. The sixth year of a proposed 7-year test, undertaken to determine the effect of feeding molasses to dairy cows, was completed, and a test to learn the effect of feeding sprouted oats to breeding dairy cows and brood sows was extended.

The chemical division covered a rather wide range of activities, including studies of edible-canna starch and the Macadamia nut, a preliminary coffee-soil survey in Kona, Hawaii, and a study to determine the most practicable method of rejuvenating a 30-year-old coffee plantation. Attention was also given to a study of soil colloids and to the development of suitable commercial methods of preserving and utilizing the avocado. As a result of the latter study it is hoped to obtain a preserved product that can be shipped. Present quarantine regulations prohibit the shipment of the fruit in the fresh state.

The nutrition laboratory of the home economics division was transferred during the year to a substantial new wooden building occupying a floor area of 1,700 square feet. Colonies of guinea pigs were bred for use in investigations comparing the vitamin content of Hawaii and mainland grown oranges and tomatoes. Colonies of white rats were bred for use in a study of the biological value of the protein of the pigeon pea and the food value of Chinese cabbage.

The horticultural work was primarily concerned with investigations relating to coffee culture and the establishment of improved varieties of fruits and nuts in the Hawaiian Islands. The coffee investigations included the accumulation of propagating material of different species and varieties, growing seedlings to permit study of vegetative methods of propagating desirable varieties, and further studies on the cultural and pruning requirements of the tree. Numerous problems in connection with the Macadamia-nut industry were attacked. This industry is being substantially developed on several plantations and by individuals, including James H. Pauls and Ralph Moltzau, both of one of the Macadamia-nut plantations, who have successfully mastered the technic of grafting the Macadamia and have been instrumental in establishing a large commercial Macadamia-nut orchard. Investigations were continued with the large native raspberry, known locally as the akala (*Rubus hawaiiensis* and *R. macraei*). Propagating and laboratory material was collected, and the native and the best varieties from the mainland of the United States were compared. Cultural experiments at the Tantalus substation and cooperative experiments at different elevations on the island of Hawaii were begun with the akala during the

year. The citrus orchard now contains oranges (12 varieties), lemons (5 varieties), pomelos (14 varieties), limes (4 varieties), mandarins (5 varieties), and citrus hybrids (12 miscellaneous kinds). Sixty-two newly introduced fruit and nut plants were under trial.

The poultry division continued its efforts to discover a simple method for determining the sex of purebred day-old chicks, and to learn how sorehead or fowl pox is ordinarily transmitted to young chicks. Mosquitoes were found to be the principal agents transmitting sorehead to baby chicks, and the trouble was effectively overcome by screening the runs. Experiments were made to compare the feeding value for poultry of Hawaii coral and imported oyster shells. The relative merits of the "all mash" and "mash-and-scratch" methods of feeding laying hens were determined.

The soil physics division studied the factors affecting the rate and magnitude of capillary rise of water and its movement through colloidal soils when supported over a free-water table. The most important conclusion reached thus far is that capillary rise of water through sands is not a simple continuous process, but the result of two actions each of which follows a different law. The exact nature of these laws has not yet been determined.

REPORT OF THE AGRONOMY DIVISION

By J. M. Westgate and M. Takahashi

PIGEON PEAS

Numerous former plantings of pigeon peas were maintained throughout the year, and 585 hybrids were planted at the university farm, the Pensacola Street station, and the Haleakala substation. These three localities represent material differences in soil, altitude, and moisture conditions. Ten hills each of different selections were planted as a rule.

As a basis for comparison, plantings were made of the standard well-fixed strain D, which is a selection from the original plant No. 218 obtained from Porto Rico and first grown at the station in 1906. Strain D was planted in every third or fifth row, depending upon the uniformity of the soil.

The seed of early-maturing selections, planted in December, 1929, and in January, 1930, ripened June 30, 1930. An attempt is being made to develop a general-purpose type of pigeon pea (1) of medium vigor, reasonably heavy seeding habits, and fair foliage production for use as forage, green manure, and for general seed-production purposes (fig. 1); (2) of satisfactory seed and forage-production habits which will be adapted to the higher lands (3,000 to 5,000 feet in elevation); and (3) of culinary value with flavor of sufficient mildness to enable the crop to compete successfully on the market with the garden pea.

GREEN-MANURING CROPS

About 85 lots of green-manuring crops aggregating approximately 50 species, were planted on the experimental plats of the university farm, the Pensacola Street station, and the Haleakala substation.

With a few exceptions, the plants of each lot were set 6, 12, 24, and 36 inches apart in rows 5 feet apart, to learn the effect of the different spacings on yield of seed. A few standard varieties were spaced uniformly in long rows, and various sections of the rows were cut back at different heights to determine the effect on seed production. The crops that made the best growth at the lower altitudes were, in the order named, the Mauritius velvetbean (fig. 2), the pigeon pea, the jack bean, fuzzy rattle pod (*Crotalaria anagyroides*), rattle pod (*C. incana*), *C. saltiana*, sunn hemp (*C. juncea*), papapa bean (*Dolichos lablab*) (fig. 3), pega-pega (*Desmodium cajanifolium*), and *Meibomia rensonii*. At the Haleakala substation where the elevation is 2,160 feet, the blue lupine and the pigeon pea

FIGURE 1.—Experimental pigeon-pea plantings, University of Hawaii

were more satisfactorily grown. None of the green-manuring crops at the higher elevations bore satisfactorily, apparently because of the cold, wet weather prevailing at the time the plants were growing. Most of the same kind of plants at the lower elevations (50 to 100 feet) produced excellent crops of seed.

FORAGE GRASSES

Plantings of the more promising forage and soiling grasses were maintained at the university farm, the Pensacola Street station, and the Haleakala substation. At each place the plantings formed a convenient source of propagating material for distribution to dairymen and others desiring to grow one or more of the available species. The more popular grasses are the Mexican grass (*Exophorus unisetus*), Napier grass (*Pennisetum purpureum*), Merker grass (*P. merkerii*), kikuyu grass (*P. clandestinum*), and Rhodes grass (*Chloris gayana*).

ROOT CROPS

Various root crops were grown at the three principal branches of the station. Some 16 varieties of wet-land taro were grown at the

FIGURE 2.—Mauritius velvetbeans, May, 1930, Pensacola Street station

university farm, where there is ample water for irrigation. About 29 varieties of dry-land, wet-land, and Japanese taro, over 60 varieties of sweetpotatoes, and several strains of edible canna and cassava

were under test at the Pensacola Street station. Dry-land taro and edible-canna plantings were maintained at the Haleakala substation, where they serve as a source of propagating material for those desiring to make experimental plantings of the crops.

FIGURE 3.—*Dolichos lablab* as a green-manuring crop, May, 1930, Pensacola Street station

LETTUCE BREEDING

Experiments to develop lettuce plants which will head satisfactorily at low altitudes in the Tropics, begun a number of years ago at the

Pensacola Street station, are still in progress, and some of the outstanding hybrids are now being tested. (Fig. 4.) Two of the hybrids are segregating very badly, and two plants, presumably hybrids, appear to be stable, notwithstanding the fact that hybrids seemingly can not be stabilized in the first two or three generations. However, regardless of whether these two plants are hybrids, they seem to be the most promising of the lot under test. An attempt is also being made to select from the segregating hybrids several good types of leaf lettuce for use in table garnishing.

MISCELLANEOUS NOTES

Owing to the impracticability of obtaining an agronomist during the year, the station merely maintained various miscellaneous plantings at the Pensacola Street station and recorded routine data regarding them. These crops included several varieties each of corn, beans, tobacco, chili peppers, alfalfa, and sweetclover.

FIGURE 4.—Lettuce-breeding plats, June, 1930, Pensacola Street station

REPORT OF THE HALEAKALA SUBSTATION

By H. F. WILLEY

At the Haleakala substation some 1,400 feet of fence was shifted in a readjustment of the fields and pasture areas. Approximately 300 feet of piping was laid for the purpose of extending the water system. A temporary wooden building, 14 by 20 feet, was built for use as a seed house. About 245 varieties of 100 different species of vegetables, fruits, and field crops were under test, including dry-land taro and sweetpotatoes (13 varieties of each), tomatoes (15 varieties), grapes (16 varieties), field corn and pop corn (7 varieties), watermelons (12 varieties), muskmelons (16 varieties), and 85 lots of green-manuring crops representing approximately 52 species. Distributions of improved planting material included 2,500 cuttings of sweetpotatoes, 3,000 cuttings of Uba cane, twenty 1½-ton truck

loads of Napier and Merker grass cuttings, 250 pounds of edible-canna tubers, 400 strawberry plants, 20 banana plants, 5 avocado seedlings, and 4,500 pineapple plants. The eucalyptus trees that were planted at the substation many years ago have grown remarkably well and in addition to making effective windbreaks supplied all the fence posts needed at the station during the year.

Extension work on the island of Maui was taken over by the extension division at the beginning of the year. This change enabled the superintendent to devote his entire time to substation work. The principal activities of the substation included testing approximately 600 selections and hybrids of pigeon peas (*Cajanus indicus*); growing 85 lots of green-manuring crops (fig. 5) representing 52 different species set different distances apart in the rows to determine the effect of spacing on seed production; testing various green-manuring crops for pineapples; determining the relative merits of pineapple

FIGURE 5.—Green-manuring crop tests, Haleakala substation. Lupines at left; *Dolichos lablab* at right

shoots, slips, and crowns for use as planting stock; and studying the effect of various rates and kinds of fertilizer application on size and total yield of pineapples. The cooperative pineapple plantings near Olinda, at an elevation of 3,300 feet, were continued to determine the possibility of extending the commercial culture of the crop to that elevation.

REPORT OF THE WAIAKEA SUBSTATION

By R. K. PAHAU

The work of the Waiakea substation was largely a continuation of studies of the cost of producing sugarcane, but a small dairy herd and a piggery were maintained. The Waiakea substation was established July 1, 1921, and will be formally closed August 31, 1930. The original purpose of the station was to carry on both experimental and demonstration work with sugarcane and to a lesser extent with diversified crops and with livestock. The station has been operated

as a demonstration sugarcane-growing homestead since 1925 rather than as an experiment station, and an exact account of the cost of raising and delivering the cane to the mill has been kept since that time. Beginning July 1, 1927, the station has been operated on a self-supporting basis, the receipts from the sale of the sugarcane being used for operating purposes. Cost-production figures, kept over a period of 10 years and on file at the University of Hawaii, should be of interest to those who are concerned in sugarcane homesteading in Hawaii. These data give definite information as to the actual cost of growing sugarcane on a 62-acre tract under the conditions at Waiakea.

REPORT OF THE KONA SUBSTATION

By R. K. Pahau

The Territorial Legislature in 1929 appropriated $5,000 for the establishment of a substation in the Kona district, Hawaii. Several inspection trips had to be made before a suitable location could be found and title to the land was not obtained until April 8, 1930. The award of contract for building the superintendent's residence and for installing a suitable water system was made June 3, 1930, at a total cost of $4,440. The 3-acre area of land on which the substation is located will be used as a working center from which various lines of experimentation can be operated throughout the region. Cooperative experiments, begun with suitably located persons during the year, included studies in representative coffee plantation to increase yield and develop improved strains; pollination studies with coffee flowers; studies of the relative merits of any one coffee plant with those of two of the same kind of plants in a place system; tests and selections of Hawaii raspberries (akala berries); and further tests and observations on the Macadamia-nut tree, the avocado, and various species of citrus and coffee. With the establishment of a substation at Kona it is possible to prosecute the present lines of work more effectively than would have been the case under the old conditions.

REPORT OF THE ANIMAL HUSBANDRY DIVISION

By M. Maneki

CATTLE

The head of the animal husbandry division was absent from the station on sabbatical leave and exchange arrangements for the entire year, but the work as previously developed by him was successfully carried on in his absence. The dairy of the university is maintained in a dual capacity. It furnishes a functioning herd for instructional purposes at the university and also animals for use in experiments made by the Federal experiment station. The dairy herd now numbers approximately 60 animals of different ages, and an attempt is being made to keep about 30 of the cows in milk throughout the year. (Fig. 6.) The experiment begun by the university to determine the effect on cows of feeding them a ration containing 25 per

cent of sugarcane molasses was continued. This experiment is now at the end of its sixth year and will probably be carried on for another year. All the cows not otherwise under special test are receiving the ration. During the year six representative cows were used as a special control group to permit study of their behavior prior to placing them on the molasses ration. Twenty-four cows are receiving the molasses ration, while the six cows in the control group are being fed a ration in which the molasses has been replaced by grain concentrates in the proper proportions.

The animals are weighed on or near the fifteenth of each month. Notes are being kept of the milk flow and breeding ability of the adults, and of the general health of the offspring. Fat tests of the milk are made once a month, the samples being taken from four consecutive milkings of each cow. Individual milk weights are taken at each milking, and the daily feed consumption of each cow

FIGURE 6.—Experimental dairy herd, University of Hawaii farm

is recorded. Service and calving dates and weight and sex of calves are also recorded, and graphs are on file showing the monthly milk production of each cow.

Tests are being made of the effect of feeding sprouted oats to breeding dairy cows. Half the animals failing to conceive are used as controls. As yet the data accumulated are not sufficient to permit drawing definite conclusions.

SWINE

The university farm maintains a small piggery of both Berkshires and Tamworths. These animals are used largely for instructional purposes, and their progeny is loaned for study to young men specializing in animal husbandry. The herds are also available for use in experiments undertaken by the Federal experiment station.

During the year an experiment was undertaken to determine the value of feeding sprouted oats to swine to overcome sterility.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton, C. Richter, and Elizabeth V. Harrold

EDIBLE CANNA

Studies begun in 1929, comparing the properties of edible-canna and potato starches, were completed, and a manuscript entitled, "The Physicochemical Properties of Edible-Canna and Potato Starches" was submitted for publication during the year. It was concluded among other things that (1) in a comparison of viscosity and swelling power by the methods devised in this work the former is not directly proportional to the latter; (2) the product of the concentration of starch times swelling power shows a fairly good proportionality with viscosity; (3) the curves of concentration times swelling power and viscosity for a number of potato and edible-canna starches roughly coincide; and (4) plotting the composite curve of the concentration-swell product and viscosity on semilogarithmic paper on the logarithmic scale causes the graph to become a straight line. This relationship makes it possible, by determining the swell at any given concentration, to find the viscosity in centipoises either by reference to a curve or by substitution in the equation of the curve. The swelling-power method, although not any more accurate than the viscosity determination, offers an advantage for factory control since it is rapid in operation and requires only simple apparatus.

Comparison of the properties of edible-canna and potato starches showed marked similarity with respect to temperature, length of time of cooking, and effect of electrolytes on viscosity and swelling power, canna starch being somewhat more affected than potato starch. In a continuation of the study of the relation of electrolytes to the properties of starches, depression in swelling power of the starches was found to coordinate closely with the valency of the cation, the numerical value of the depression being approximately 20 for monovalent, 30 for divalent, and 70 for trivalent cations. Treating raw starches with neutral salts of monovalent cations increased the swelling power and viscosity, whereas treating the swollen granules with the same kind of salts caused a depression. This was attributed to two different phenomena—the former being a chemical replacement of the cations of the starch granule with the monovalent cations, the starch of which had a greater swelling power than the original, and the latter, a physical adsorption which resulted in reduction of swell.

The extent of the substitution of the cations of neutral salts for those in the raw starch granule depends on the concentration of the salts and the number of treatments given. The effect of removal of the cations on the properties of the starch was studied by treating the starch with weak hydrochloric acid and by electrodialysis. Acid at a concentration equivalent to 0.002 had an effect comparable with electrodialysis. In nearly all instances removal of the cations caused the granules to burst on swelling. The fact that electrodialysis also produced this effect shows that bursting of the granules was not due to hydrolysis of the organic complex. Attempts to restore the original properties of the starch by resubstituting the cations were not successful by the method used, viz, that of shaking the starch with neutral salts and removing the excess by subsequent washing.

Investigations of the causes of differences in the properties of starches of the same species were continued. In both potato and canna starches preliminary data indicated that the high-viscosity starches were less saturated with cations, as was indicated by pH and titration curves, than were those of low viscosity. They also contained smaller amounts of calcium removed by displacement with sodium chloride and by electrodialysis. Potato starches contained markedly greater quantities of cations and phosphoric acid than canna starches.

The relative ease with which one cation may replace another in the raw starch granule suggested the possibility of government of the cations of the starch granule in the plant cell by the nature and concentration of the cell sap. If this were true, starches grown in

FIGURE 7.—Edible-canna plants growing in water culture to determine the effect of ion variation

the same locality over a period of years, or in various localities, would probably differ in electrolytes because of the variable factors of climate and culture. In the process of manufacture the use of water containing appreciable amounts of salts, or the use of bleaching agents, would seemingly alter the original cation content of the starch. It would also seem that these easily replaceable cations might serve an important function in the metabolism of the plant cell.

A new investigation was begun to determine the variations in the total and replaceable electrolytes contained in starches grown under different conditions of climate and culture. An attempt is being made to grow canna rootstocks in water culture for the production of a series of starches from plants grown under conditions differing greatly in the nature and the total concentration of the electrolytes used. (Fig. 7.) Methods are being developed to determine differences in the bonding of the cations to the starch granule, whether

they exist in different degrees of replaceability, and whether they have any relationship either to the cell sap or to the viscosity and swelling power of the starch.

Results of a commercial trial of a 6-ton lot of edible-canna starch were received by the station from a large starch distributor of the mainland. The distributor found the starch to be well adapted for use in making dextrin and for finishing textiles, two of the largest uses for the special starches. Canna starch could therefore be used as a substitute for cassava starch in dextrin and for potato starch in textile sizing.

MACADAMIA NUT

Further investigation of the variation in the composition of Macadamia nuts bore out the results previously obtained—viz, that maturity probably more greatly affects composition than do differences in climate and soil, or seedling variation. The oil content of the nut appears to increase and the sugars to decrease until the outer hull turns brown. Strong winds, or physiological conditions of growth, often cause a variable proportion of partly mature nuts to fall, with a consequent variation in the average composition of samples taken at different times from the same tree. The chemical division, working in cooperation with a local grower, selected 12 Macadamia-nut trees for study at biweekly harvests throughout the season. The various factors which affect composition and roasting qualities of the nuts were investigated. Samples of nuts from these trees are also to be used in a further study of improved methods for dividing nuts according to maturity.

Methods of grading Macadamia nuts according to the specific gravity of the unshelled nut have not been found to be entirely satisfactory because of the great variation in the thickness of the shell. The group with a specific gravity of less than unity contains some thin-shelled nuts with marketable kernels as well as badly shrunken, immature kernels. Work was therefore begun to learn the relation of the specific gravity of the kernel to its composition, in the hope of securing a more nearly accurate criterion for grading. To learn the degree of correlation between the oil content and the specific gravity, a series of nuts were selected covering the entire range of specific gravity from 1.05 to 0.96, and the oil and specific-gravity determinations were made, a single nut being used for each sample. Plotting these values gives a curve which shows very good correlation. With few exceptions, the deviation from the curve is less than 1 per cent. This method offers excellent possibilities as a rapid means of grading Macadamia nuts.

Experiments were begun to find the relation of roasting qualities to composition. The immature nuts when cooked in oil were found to turn dark rapidly and to develop a strong, rather unpleasant flavor, and a hard or tough texture. Under similar conditions of cooking the mature nuts were light brown, mild in flavor, and of crisp texture. The approximate dividing line between the desirable and the undesirable nuts is a specific gravity of 1, which on the curve is equivalent to an oil content of about 70 per cent. Nuts of a specific gravity greater than 1 did not seem to be satisfactory

for roasting purposes. The roasting qualities of the nut did not change perceptibly when the oil content was above a certain percentage.

As a result of the analyses made during the past two seasons, it is thought that two distinct varieties of Macadamia nuts are being grown in Hawaii. (Fig. 8.) The varieties differ outwardly in the surface of the shell, one being smooth and the other rough, and they differ in composition, the smooth-shelled variety containing an average of 76 per cent of oil and 4 per cent of sugar; whereas the rough-shelled variety contains an average of 67 per cent of oil and 8 per cent of sugar. In appearance, flavor, and roasting qualities, the two varieties are noticeably different. The smooth-shelled nuts have a crisp, nutty, but rather unpronounced flavor, whereas the rough-shelled nuts are less crisp and of a more pronounced, sweeter flavor. The roasting qualities of the rough-shelled variety are similar to those of the somewhat immature nuts of the smooth-shelled type.

FIGURE 8.—Two varieties of Macadamia nuts grown in Hawaii: A, smooth-shelled variety, high in oil and low in sugar; B, rough-shelled variety, low in oil and high in sugar

COFFEE

SOIL SURVEY

The chemical division, in cooperation with the geologist of the Volcano Observatory, Geological Survey, continued its studies of the origin of the soils of the Kona district of the island of Hawaii. The evidence thus far obtained indicates that a definite mantle of volcanic ash gives rise to the fine uniform texture observed in certain areas of the Kona slope. Samples of the ash mantle at different altitudes, and of the decomposed scoria of the a-a lava flows were taken for analysis. The difference in origin is believed to furnish a feasible basis for a soil survey of the Kona district.

REJUVENATION OF OLD PLANTINGS

A cooperative experiment was begun in the Hamakua region, Hawaii, to determine the best method of renewing a 30-year-old coffee planting. For many years the trees have been kept topped, but they have not been pruned systematically. As a result they have made little growth and are largely a mass of old, unproductive laterals. (Fig. 9.) Methods under trial for renewing growth include

drastic thinning and pruning back; cutting off the trunk 1 foot aboveground to induce new top growth; and replacing dead and worn-out trees with seedlings from the Kona and the Hamakua districts. A fourth plat is being left to serve as a check, the trees there receiving no pruning. The experiment is being tried in a high, poor region, and also in a low, rich region. It is planned to fertilize one-half of each plat in the Hamakua district to demonstrate the practical value of fertilizers for coffee. No fertilizer has been used in this region.

SOIL-COLLOID STUDIES

Methods of measuring soil colloids were further studied by G. Richter, assistant chemist. The Bouyoucos' hydrometer method, which has become rather widely used since its proposal by Bou-

FIGURE 9.—Coffee tree about 30 years old showing the effect of continuous topping without thinning out of the laterals. The entire top has been partly lopped off to induce new growth from below. (June, 1930)

youcos in 1927, was investigated for application to tropical Hawaii soils. This method, which is based on Stokes' law of settling particles, was compared with the pipette method of mechanical analysis. The rapid hydrometer method, as suggested by Bouyoucos, for use when the variations in the specific gravities of soils are not taken into consideration was found to be sufficiently accurate for the routine classification of soils. The specific gravities of the soils used in this study varied between 2.2 and 3.3. This variation is much greater than in the case of mainland soils. A much better agreement was obtained between the pipette method and the detailed hydrometer method, which takes into account the specific gravity of soil and temperature conditions.

The temperature correction in the hydrometer method of mechanically analyzing soils, as proposed by Bouyoucos, was investigated.

He says that the corrections made should be the same for measuring all soil-suspension concentrations. The hydrometer is calibrated to give correct readings (grams solid matter per liter of water) at 67° F. Under or above this temperature 0.35 is deducted from or added to the readings for each degree under or above, respectively, 67°. The concentration of soil suspension and the range of temperature were found to play a rôle in the correction factor. Suspensions of the same soil at different concentrations but at the same temperature fail to give concordant results when the temperature-correction factor of 0.35 is applied for all concentrations. The same soil suspension which gives a certain reading at 67° will not give the same result at a higher or a lower temperature if the temperature-correction factor of 0.35 is applied unconditionally. In order to obtain concordant results, the correction to be applied per degree of Fahrenheit must become considerably smaller at the lower range of the hydrometer than at the higher range. Moreover, the corrections to be applied below 67° are different from those to be applied above 67°. On the basis of the findings a sliding-scale correction table to give concordant results at all concentrations is tentatively suggested.

Studies were begun to investigate the relationship between physical properties, especially moisture characteristics and the replaceable cations of the soil-exchange complex. For this purpose several varying soil types were saturated with the more common monovalent and divalent cations of the soil solution. The cations chiefly studied were hydrogen, sodium, potassium, ammonium, calcium, and magnesium. With mainland soils cations in the absorbed state were found to exercise an influence over physical properties. In addition to the theoretical importance of the investigation, certain practical considerations were found to be linked with the base-exchange and base-saturation phenomena, including the application and fixation of soluble fertilizers, the formation and accumulation of soil acidity, alkali-land reclamation, and the application of soil amendments, notably calcium. The question has long been debated whether the continuous application of sodium fertilizer results in undesirable changes in such physical soil properties as stickiness, plasticity, rate of water percolation, and texture. This investigation purposes to throw light on this question.

The estimation of the colloidal content of soils by the water-vapor adsorption method was studied with Hawaii soils. This method is based on the assumption that certain physical properties, such as water-vapor adsorption, are due largely, if not exclusively, to the colloidal fraction of the soil. The amount of colloids is estimated by determining the water vapor adsorbed by a soil and by a representative portion of the colloidal fraction of the soil which has been extracted. The ratio of the two figures obtained multiplied by 100 is taken as the percentage of colloidal material in the soil. This method fails to give correct results in many instances with both mineral and organic soils. The percentage of the so-called colloidal material, as estimated by this method, has been compared by several investigators with the colloidal-matter content as determined directly by sedimentation, assuming Stokes' law (pipette method).

The values obtained in the adsorption method are much higher than those obtained in the sedimentation method, the increases amounting to several hundred per cent in some instances. Similar results were obtained with Hawaii soils of both high and low organic-matter content.

No satisfactory explanation is advanced relative to the large disparity existing between two methods which are supposed to indicate the same thing. Organic material was often found to be present to considerable extent in the different silt fractions of Hawaii soils. This finding invalidates the assumption that all the organic material exhibiting adsorbtivity obtains in the colloidal fraction. Although all such organic material might really be of colloidal dimensions, existing in aggregates and resisting successfully all efforts of dispersion, it would nevertheless be classified as noncolloidal for all practical purposes. Furthermore, the chemical composition of the various fractions of the same soil, as indicated by the silica-sesquioxide ratio, vary considerably. For example, in one instance this ratio in the clay fraction amounted to 1.25, whereas in the silt fraction the ratio amounted to only 0.07. In another instance, the figures were 0.62 in the clay fraction and 1.41 in the fine silt fraction. It is known that the different chemical compounds involved in the inorganic phase of the soil differ widely in water-adsorbing properties, and that particles of much larger than clay or colloidal dimensions give considerable water-vapor adsorption. As a result of the investigation of the water-vapor adsorption method it seems inadvisable to attempt to translate physical properties into particle size, especially with soils of high organic-matter content, or with soils in which the chemical composition of the various fractions varies considerably.

AVOCADO PRESERVATION AND UTILIZATION

Studies of methods of preserving the avocado and its by-products were made during the year by E. V. Harrold, assistant chemist. Extensive work was done in canning, various methods of storing and freezing the fruit were tried, and special attention was given to methods of dehydration, pickling, and oil extraction.

In August, 1929, experiments looking to the development of the most practicable methods of utilizing the avocado were begun. The quarantine in effect on the fruit in the fresh state makes it necessary to process the avocado for exportation. The attack of investigators in other parts of the world on the problem was first studied. During the year over 200 different avocado formulas or recipes were tested.

Avocado-tomato cocktail combinations were tried in which green fruit and ripe fruit and fruit sauce containing different amounts of acid were used. The combinations tried were both hot and cold, and made with and without sodium benzoate. Different temperatures and lengths of time of cooking were tried with storage at 31° F. and under room temperature. Most of the samples spoiled or developed a rancid taste, and the cooked samples were bitter. A pleasing product was made by adding to avocado cubes in glass jars cocktail sauce which had been strengthened by the addition of

one-half of 1 per cent of acetic acid as vinegar. This product must be used within two weeks after it is removed from cold storage.

A tasty sandwich paste was prepared by putting peeled avocado through a meat grinder having a nut-butter attachment, and adding to 5 parts of the pulp by weight 1 part each of chopped sweet pickle, chopped pimento, mayonnaise, and 1 part of 100-grain vinegar, and finally one-tenth of 1 per cent of sodium benzoate. The bottles were filled to prevent excess browning of the contents by oxidation and then stored at 31° until wanted for use.

Fruit which was sulphured, presoaked in alcohol, pretreated with sugar, or with acid or salt, and then sun-dried, or dehydrated in a hot-air oven with a forced draft under different temperatures, became bitter, lost flavor and color, and upon being resoaked in water failed to regain texture, was of salvelike consistency, and very unpalatable.

Although canning the avocado in water, brines, diluted acid or sugar solutions, and heavy sirups resulted in an unsatisfactory product, a method was found of retaining the natural green and yellow coloring of the fresh fruit, which upon being heated turns mustard yellow in color. In this method avocado cubes, halves, or slices are soaked in pineapple vinegar until the liquid penetrates them. They are then removed from the vinegar and processed at 212° F. for at least 10 minutes, or at 160° for 20 minutes. The colors are obscured by the soaking process but are restored when the fruit is subjected to the temperatures above mentioned. When "60-grain" vinegar containing 6 per cent of acetic acid is properly used it seems to restore the natural colorings of the fruit. Vinegar of higher acidity was also found to restore color. Six per cent was satisfactorily used as the minimum strength in tests at the station. Avocados when thus treated to restore coloring may be combined with an equal amount of canned crushed pineapple to which fruit spices siruped with a 50 per cent sugar solution have been added. The combination should be exhausted for 10 minutes and processed for 30 minutes at 160° F. The sirup may be omitted.

Ripe and green avocados were placed in brines having strengths ranging from 5 to 20 per cent, and left under ordinary room temperature. Examination of the fruit at the end of one and two months showed that it was apparently perfectly preserved. However, after the fruit had been placed in fresh water to extract the salt, it was found to have lost its flavor, although in color and texture it remained perfect. Small, whole fruit when stored in brines having strengths ranging from 15 to 20 per cent kept well, but did not prove to be palatable. Tannin from the seed and from the skin permeated the fruit and predominated in the flavor.

The hard, green fruit from the above-outlined experiment was put up in pickle form in which sour, sweet, sweet-spiced, and salt-spiced liquors were used (*4*).[1] The spiced products were especially good, but none of them retained a distinct flavor. Any vegetable or fruit may be used as the pickle to flavor the avocado.

Olive-pickling treatments tried on the avocado were not successful. Oil was obtained from the fresh pulp of the avocado by the use of two methods without the preliminary dehydration usually con-

[1] Italic numbers in parentheses refer to Literature Cited, p. —.

sidered to be necessary. In the first method tried the finely mashed pulp was mixed with kieselguhr in the proportions of 6 to 1. It was then made into a press cake held in cheesecloth and put in a hydraulic press. Pressure was applied slowly at first and was strengthened when most of the moisture had been eliminated. In the second method tried a gallon of warm 2 per cent brine was added to about 5 pounds of mashed pulp and the whole allowed to stand for five days. It was then put through a supercentrifuge. Dehydrated avocados gave 2.5 per cent of dark, bitter oil that required much washing with alcohol and hot water. Under the pressure method the fresh pulp required only a few washings with warm water and when filtered gave 2.75 per cent of sweet, light, amber-colored oil. Under the centrifuge method the fruit gave 3.5 per cent of clear, light-green oil. Some of the chemical properties of these oils were compared. It is hoped that the iodized oil from the avocado can be successfully used in medical Röntgen-ray work. Experiments along this line are now under way. The press cake from the fresh fruit contains much protein, has a high fat content, and may make a good feed for live-stock. The dehydrated press cake can not be used because of its bitterness.

Cold-storage tests made under various temperatures with the whole fruit showed that the effect of time and temperature of storing varies with the variety. As a whole, Hawaii-grown avocados may be stored green at 36° F. for six to eight weeks. The fruit when removed from this temperature ripens satisfactorily within two to five days. Different kinds of paper wrappings and coatings of paraffin were tested to determine their value in prolonging the life of the fruit in storage. Results of these tests showed that the storage period should be even shorter, instead of longer, and that the fruit develops off flavors and colors. Fruits which were coated with paraffin rotted without ripening. Avocado cubes and halves were stored under temperatures ranging from 0° to 20° in diluted brines, vinegar, sirups, and water in paraffined cartons, in glasses, and in tin cans. Results showed that the containers should be tightly sealed to exclude foreign odors and air and prevent the browning of the fruit by oxidation. The frozen product can be kept indefinitely. The texture of the fruit was found to have gone completely when the samples were allowed to thaw, but the color was good in all instances and the sirups were of excellent flavor.

A satisfactory avocado pulp for use in ice cream was made by mixing 1 part of sugar with 5 parts of pulp and storing the mixture in sealed containers at 0° F. Having this pulp ready for immediate use was found to be advantageous. Plain and lightly salted pulps did not retain their color or flavor well. The pulp when mixed with a small amount of vinegar was satisfactorily used with salads and relishes, and for sandwiches.

Quickly freezing the whole fruit with carbon dioxide "snow" was not found to preserve the fruit satisfactorily. However, under proper conditions of freezing at −40° F., with subsequent storage at −10° or at zero, this method might be used to advantage. Hard, green fruit which was frozen did not ripen after it was removed from storage.

Results of quickly freezing the fruit in tin cans sealed in the air and sealed in vacuum without any liquid covering showed that the

vacuum pack was superior to the air-sealed product in color, texture, and flavor. Different varieties of fruit behaved differently when they were frozen. The Itzamna, Macdonald, and Wagner varieties of avocado gave the best results in texture of the lot tried, although none of the products had a distinctive avocado flavor. Freezing and prolonged storage seemed to destroy or to impair the flavor. Fruit which was frozen for four days was of excellent flavor when thawed.

Avocado halves which were frozen in direct contact with carbon dioxide "snow" and then stored for several months in screw-cap glass jars at zero retained a texture hardly distinguishable from that of the fresh fruit, but the product was flat and tasteless and after six weeks in storage lost its color.

The quininelike bitter principle that forms in the avocado when heated was a decided handicap to success in nearly all the work undertaken with the fruit. The bitter principle is soluble in ether,

FIGURE 10.—New nutrition laboratory, University of Hawaii campus. Dairy buildings in right background

alcohol, and water. Its occurrence in the fruit is enhanced by treatments with weak acid, such as citric, tartaric, and acetic acids, but appears to be destroyed by 1 to 2 per cent solution of hydrochloric acid. Slow or quick freezing was found to destroy the bitter principle, or the components that cause it. Results of many experiments confirmed this fact with all the varieties of avocado tested.

REPORT OF THE NUTRITION LABORATORY OF THE HOME ECONOMICS DIVISION

By CAREY D. MILLER

A substantial wooden building occupying a floor space of 1,700 square feet was built and equipped as a laboratory during the first half of the year. This building is to serve as the nutrition laboratory. (Fig. 10.) Its facilities are excellent for assaying food, both chemically and biologically.

BREEDING ANIMALS FOR EXPERIMENTAL PURPOSES

A white-rat colony begun with 16 young animals in September, 1929, contained 26 rats of breeding age in June, 1930. During this period 153 healthy rats were born and used for breeding and other experimental purposes. Some difficulty in breeding was overcome by changing the feeding and housing arrangements.

The guinea-pig colony, begun with 6 animals early in the year, increased to more than 50 animals. A number of the pigs were unfortunately lost when they were treated for lice with sodium fluoride in too generous quantities.

VITAMIN C CONTENT OF ORANGES AND TOMATOES

A preliminary experiment comparing the vitamin C content in Hawaii and California grown oranges was begun during the year. The juice was fed to nine guinea pigs. As a result of the experiment the juice of the Hawaii-grown orange was found to be equal to that of the California-grown fruit in antiscorbutic properties. The experiment had to be discontinued sooner than was desirable, because the orange season came to a close more quickly than was expected. The experiment will be repeated during the local orange season, beginning in the fall of 1930.

Fifteen guinea pigs were used in a preliminary experiment comparing the vitamin C content of mainland canned tomatoes and locally and mainland-grown tomatoes in the fresh state. The negative control group was fed only a basal diet, whereas the positive control group was fed ample supplies of orange juice. The negative control group was fed the pulp of Hawaii and mainland grown tomatoes in the fresh state. Short periods of feeding and examination under the miscroscope of the teeth and the jaws of the animals, as is recommended by Hojer (*3*) and later by Eddy (*2*), are being employed in the experiment. Microscopic analyses have not been completed, but the indications are that locally grown tomatoes in the fresh state are higher in vitamin C than are similar tomatoes from the mainland. The superiority of the Hawaii-grown fruit is probably due to the fact that it is picked when fully ripe, whereas tomatoes from the coast region of the mainland must be picked when green for shipping to Hawaii. The experiment was temporarily closed, pending the breeding of sufficient animals for continuing it.

BIOLOGICAL VALUE OF THE PROTEIN OF THE PIGEON-PEA SEED

Forty-five rats were used in a preliminary experiment undertaken to determine the biological value of the protein of the seeds of the pigeon pea (*Cajanus indicus*). Ground pigeon-pea seed meal was fed in comparison with casein to determine the relative value of the two forms of protein. In future experiments purified protein from the pigeon-pea seed meal will be used. When pigeon-pea seed meal was fed in sufficient quantities to furnish 18 per cent of protein in the ration of white rats, growth and reproduction were satisfactory. This quantity of pigeon-pea seed meal also seemed to be sufficient to furnish enough of vitamins A, B (F), and G for normal growth. The pigeon pea is a very important stock feed in Hawaii, and the results of this preliminary experiment make it advisable to continue the study of the protein value of the crop.

CHINESE CABBAGE AS A FOOD

Chinese cabbage (*Brassica chinensis*) is one of the principal vegetables used in the dietary of the orientals in Hawaii. It is served both in the fresh and in the salted state. To date 34 rats have been used in an experiment testing the value of the vegetable, but it is too soon to draw definite conclusions.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

COFFEE

Coffee occupies a comparatively small place in the agriculture of Hawaii, although as an industry it ranks fifth, following sugarcane, pineapples, beef production, and poultry raising, in the order named. Approximately 50,000 bags of coffee have been exported from Hawaii annually within recent years. Most of the regions in which coffee is grown in Hawaii are particularly adapted to its culture, as regards soil, temperature, and moisture, and protection from the prevailing trade winds. In many places the clouds afford a natural shade during the warmer parts of the day in summer.

Most of the growers lease the land from large landowners, and some of them plant the seedling trees entirely too close. Close planting may give early and perhaps larger returns per acre than would be the case if the trees were set farther apart, but in the course of 10 or 12 years it causes crowding to such an extent as to reduce yields materially. Crowding probably may be retarded somewhat by frequent pruning of the trees, but too much severe pruning soon results in stunted trees.

Very little attention is given to the selection of propagating material, and practically all the trees grown are seedlings. Propagation by seedlings is the natural method of producing numerous variations, but it lessens the margin of profit for the grower. A greater production on the same area of land will give increased returns. This will naturally encourage an extension of the area in coffee and cause the utilization of lands which at present are not producing commercial crops of any kind.. The vital problem now confronting the coffee growers of Hawaii is that of increasing the production of high-grade coffee. Any possible increase in local production would be so small in comparison with the amount of coffee consumed in the United States as to have no effect on the selling price of coffee in American markets. Following the customary methods usually practiced in improving commercially grown tree crops, experiments now in operation have been planned with a view to standardizing Hawaii coffee by vegetative methods of propagation.

Top grafting mature fruit and nut trees is sometimes deemed necessary, especially when a growing period of 7 to 10 years is required for the tree to come into profitable bearing. Top grafting is not so important, however, with coffee trees which naturally come into profitable bearing in three to four years. It is important also that consideration be given to the selection of rootstocks which are resistant to unusual soil conditions, and particularly to nematode attack.

The species and varieties of coffee in Hawaii are not numerous, and difficulty in getting the different kinds of material for trial has considerably delayed the testing of resistant rootstocks. The only propagating material obtained by the Hawaii station from outside the Territory in recent years has been seeds of *Coffea arabica*, *C. excelsa*, *C. robusta*, *C. bukobensis*, *C. liberica*, and *C. quillou*. These were obtained from the Amani Research Institute, Amani, Tanganyika Territory, Africa. The seeds arrived at Honolulu in 1927, but were held by the Bureau of Plant Inspection. They were then forwarded to the Bureau of Plant Industry, United States Department of Agriculture, at Washington, D. C., and grown in quarantine for one year. The plants were then sent to Hawaii, where they were again kept in quarantine for another year before being utilized in the experiment. In January, 1930, sixteen 1-year-old plants of Hawaii coffee (*C. arabica*, No. 5497)[2] were obtained from W. A. Meyer, of Pukoo, Molokai, Hawaii. This particular stock is said to have been isolated for 50 years.

Coffee seedlings used in the experiment during the year included 460 Hawaii coffee trees (No. 5383) grown from station seed, 380 of which were distributed for cooperative experiments; 50 trees (No. 5381) from seed from Tanganyika Territory; 4 trees (No. 4135) from seed from a coffee company of Kona, Hawaii; and 32 trees (No. 3948) the original stock of which came from Java in 1917—all of the Arabian group (*C. arabica*); 13 Excelsa trees (No. 3947, 12 trees, the original stock of which came from Java, and No. 5382, 1 tree from seed from the United States Department of Agriculture)—all of the Liberian group (*C. excelsa*); and 1 Robusta tree (No. 5948) of the robustoid group (*C. robusta*) from seed from Tanganyika Territory.

About 200 seedlings of these coffees were planted at the Tantalus substation at an elevation of about 1,000 feet. Most of the trees were set on a hillside which is somewhat sheltered by large mango and eucalyptus trees. The coffee has not done well in the more heavily timbered plats, but it has made fair growth in the clearings and in the areas of medium to light shade.

Vegetative methods of propagation with the small amount of material available at the Pensacola Street station gave little satisfaction, probably because the material used was in rather poor condition. Seedlings which were grown in compartively small containers were hard to get into proper condition for grafting.

Methods of pruning coffee trees were studied in the Kona district of Hawaii. Several methods are employed by the growers, but none of them offer advantages. It is believed that a system of pruning should be worked out to apply to grafted trees that are properly spaced and cultivated.

MACADAMIA NUT

Special investigations with the Macadamia nut were in progress during the year. Four hundred vigorous seedlings have been developed from the several selected trees growing at the Tantalus substation. These seedlings are to be used as rootstocks in further work developing standard varieties. The experiments are being started at

[2] Number under which the trees were received at the station.

both the Pensacola Street station in Honolulu and at the Kona substation, Hawaii. A portion of these trees is being grafted in gallon-size containers so that transplanting can be done without disturbing the soil about the roots. Others are being set in orchard form and top grafted as soon as they show evidence of having become established permanently in the orchard. Rooting cuttings as a means of propagation has not given success at the central station, even when the trials were made under several different conditions. Arrangements are being made, however, to try the method at the Kona substation where climatic and soil conditions are better. The importance of vegetative propagation is becoming more evident each year. A great many additional trees came into bearing during the early part of this year, and marked variation in the nuts of certain trees was noted. Several orchards in different parts of the Territory contain unusual trees which have come into bearing for the first time. Among these are trees with unusually large nuts and others with nuts having comparatively thin shells. The Macadamia-nut trees are also showing numerous other variations including differences in vigor, nature of foliage, time of flowering, and productiveness. During the year the horticulturist made a trip to the orchards on Oahu and Hawaii for the purpose of inspecting and studying the trees there. He found growers enthusiastic about their orchards and anxious to have them developed rapidly.

A bulletin on the Macadamia nut was issued during the year (*5*). This bulletin gives the results of experiments recently completed, and likewise a general discussion of the history, botanical relationships, and cultural requirements of this comparatively new nut tree.

AKALA OR NATIVE RASPBERRY

Six commercial varieties of raspberries—Lloyd George, Cuthbert, Herbert, Seneca, Latham, and Ranere—were introduced into Hawaii through the kindness of George L. Slate, of the New York State Agricultural Experiment Station, Geneva. These plants were in transit about 14 days. All were immediately set in 7-inch pots of sterilized soil, and some time later 61 per cent of them were found to have survived. This introduction was a continuation of the work started last year when varieties were obtained from several other parts of the mainland of the United States. It is planned to use these varieties in cultural tests and hybridizing experiments.

In the summer of 1929 further study was made of the wild native raspberry (*Rubus hawaiiensis*), several localities in the mountains of the island of Hawaii, each differing in elevation and in rainfall, being visited for the purpose. In the forest reserve on Hualalai Mountain, where the elevation is about 4,500 feet and the average annual rainfall amounts to 100 inches, akala plants make rank growth, often reaching a height of 8 to 10 feet. The crop is not large, but the individual fruits are very large and juicy. In a timber-line region on the same mountain where the elevation is about 6,000 feet and the annual rainfall varies from 30 to 50 inches, the trees are few and stunted in growth, and vegetation in general consists of scattered bushes and other small plants such as are adapted to the higher elevations of Hawaii. Akala plants 4 to 5 feet in height are found growing in many places in this region, and in early

summer they are heavily loaded with large, firm fruit, which is rather tart but of fair flavor when fully ripe. The young plants, like those in the rainy forest, apparently have developed from seeds dropped by birds. The fruit is borne on short side spurs on the young wood, each spur producing five to nine berries averaging about an inch in diameter, although larger specimens are common. Berries of both yellow and purple-fruited varieties of *Rubus hawaiiensis* were collected and put into different preservatives for laboratory work. Seeds desired for propagating purposes were prepared for shipment by selecting ripe berries and thoroughly mashing and mixing them with a quantity of rich, damp mountain soil. A few days later the material was forwarded to the Pensacola Street station, Honolulu, where it was spread as a surface layer over other prepared soil in germinating flats. (Fig. 11.)

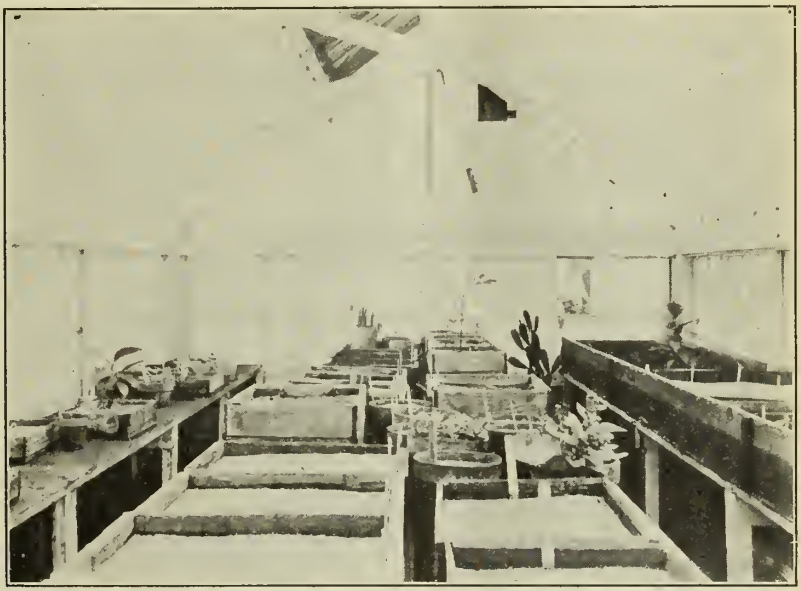

FIGURE 11.—Propagating flats used in akala seed germinating tests

During the past few years no akala seeds have germinated at the station even when they were dried for a few days before being planted. Like the seeds of many other species of tropical fruit plants, including those of the mangosteen (*Garcinia mangostana*), lanzon (*Lansium domesticum*), litchi (*Litchi chinensis*), mountain-apple (*Eugenia malaccensis*), and Brazil cherry (*E. brasiliensis*), the seeds of the akala are sensitive to drying.

In one locality on the west slope of Mauna Loa, where the elevation is about 6,200 feet, a variation of *Rubus hawaiiensis* was found growing over a considerable area of land. All the plants of this form bore oblong fruit on long fruitstalks. Individual ripe fruits were 1⅛ to 1¾ inches long. Akala plants in a near-by locality all bore yellow fruit of spherical shape and averaged 1 to 1¼ inches in diameter.

A study was made of the Rubus species growing in a part of the large Kau forest reserve on the east side of the volcano Mauna Loa.

The Kau forest is separated from that of Kona on the west side by a barren plateau which is 15 to 25 miles across and about 3,000 to 4,000 feet above vegetative growth; and also by numerous comparatively recent barren lava flows on the north and the south, extending from great fissures high upon the slope down to the sea. The Kau forest in many places is dense, particularly the underbrush, of which the akala (*R. hawaiiensis*) forms a portion. A foot trail was followed up the mountain slope to an elevation of about 5,000 feet. Practically all the akala plants observed were found to be tall and of spindling growth, a condition presumably caused by the crowded undergrowth of the forest. The crop was light and none of the fruits measured an inch in diameter. Both yellow-fruited and purple-fruited plant material was collected for propagation and laboratory purposes. All the akala plants observed in this region were spineless. The forest ranger, however, stated that spiny plants grow in some other parts of the reservation. No plants of *Rubus macraei* were seen, but at an elevation of about 3,000 feet a number of plants of the blackberry (*R. laciniatus*) were found growing. Birds presumably brought the seeds to this unusual place, as the species is common along the road approaching Kilauea Volcano from the Hilo side some 30 miles away.

Early in the year some experiments with species of Rubus were begun at the Tantalus substation on a rather steep slope at an elevation of 1,000 feet. The soil in this region is made up of decomposed volcanic cinders and supports a forest growth mostly of mango and eucalyptus trees. Shrubs, vines, and much honohono (*Commelina nudiflora*) form the undergrowth. Since both akala and coffee grow in the mountainous woods of many localities, it was thought that they might do well in this forest. Rubus plants were accordingly spaced 16 feet apart in the row and interspaced with young coffee trees, along contours. Water was provided for the plants from a near-by source in case of drought. Included among the Rubus species were 170 plants of akala (*R. hawaiiensis*) which had been grown at the Pensacola Street station from seed collected the previous year, 10 varieties from the mainland of the United States, and 1 species from the Philippines. The plants were severely attacked by the Japanese beetle (*Adoretus tenuimaculatus*)[3] notwithstanding the fact that they were given every possible care.

In September, 1929, cooperative experiments with Rubus species were begun in the Kona district of Hawaii. Plantings were made in four places varying considerably in elevation and in rainfall. Of these plantings, 18, representing 9 varieties, were set at an elevation of 1,950 feet in a very moist locality of the Macadamia Nut Co., Keahou mauka; 24, representing 10 varieties, including 6 akala plants, were set at an elevation of 1,500 feet in a moist locality on the farm of T. C. White, Kealakekua; 10, representing 4 varieties, were set at an elevation of 2,000 feet in a dry locality on the Huehue ranch, North Kona; and 10, representing 4 varieties, were set at an elevation of 2,750 feet in a very dry locality on the Puuwaawaa ranch.

[3] These beetles attack many kinds of plants of the family Rosaceae. The beetles are so numerous as not to be held in check satisfactorily by poison sprays. One horde of beetles may be fatally poisoned and be quickly succeeded by several other hordes which do additional damage to the plants before succumbing to the poison.

CITRUS

The citrus orchard maintained at the central station in Honolulu is an accumulation of miscellaneous species and varieties that were introduced from various sources. This orchard in addition to serving for experimental purposes is also a source of propagating material for use in numerous cooperative experiments throughout the Territory. The orchard is small, and at present contains 12 varieties of oranges, 5 varieties of lemons, 14 varieties of pomelos, 4 varieties of limes, 5 varieties of mandarins, and 12 kinds of miscellaneous citrus hybrids. Plants of several Siamese varieties of pomelo and half a dozen new hybrids were recently obtained from the United States Department of Agriculture, Washington, D. C. These will in time form a part of the station orchard.

Considerable interest in citrus growing, particularly oranges and lemons, is being shown in several parts of the Territory. The con-

FIGURE 12.—Pomelo seedlings of the shaddock type growing in the nursery for rootstocks for grafting citrus

sumption of these fruits has greatly increased within the past two years, importations have been much greater than ever before, and the fruit has retailed at unusually high prices. Another matter of encouragement to the local producer is the lessening in some localities of the ravages of the fruit fly on oranges, lemons, and pomelo of the shaddock type. Careful study of the requirements of citrus of this kind should enable growers to produce profitable crops on large areas of land. One of the present experiments has for its object the development of a method for utilizing the different varieties in order to extend the fruiting season over a much larger portion of the year than is now the case.

The importance of using vegetative methods for propagating the citrus is well known. Much experimental work has yet to be done in this line because Citrus species and the variations under which

they are cultivated are numerous. For good results the tree is rather exacting in its requirements of temperature, moisture, and soil. One of the present experiments deals with a study of resistant rootstocks. As has been shown by experiments in recent years pomelo seed-

FIGURE 13.—The Hak-ip variety of litchi growing at the Pensacola Street station

lings of the large-fruited shaddock type make the best rootstocks on which to graft most of the kinds of citrus in Hawaii. Such seedlings are now being used at the station. (Fig. 12.) They may be grown from seed to a suitable size for grafting in about 10

months. At this age the seedlings are 14 to 18 inches high and have a stem diameter of about five-sixteenths to seven-sixteenths inch at the point where the graft is to be made. This graft is made in the stem at a distance of 6 inches above the ground. Bark grafting or wedge grafting may be used, and the parts will be found to have united sufficiently in about two months to permit transplanting the tree to the orchard. Such seedlings can be successfully developed and grafted in the field, but in this case the scion may fail and a new seedling will have to be planted. Results of tests with the fruit of different varieties produced in the orchard show that quality is greatly influenced by the temperature and the moisture conditions prevailing during development.

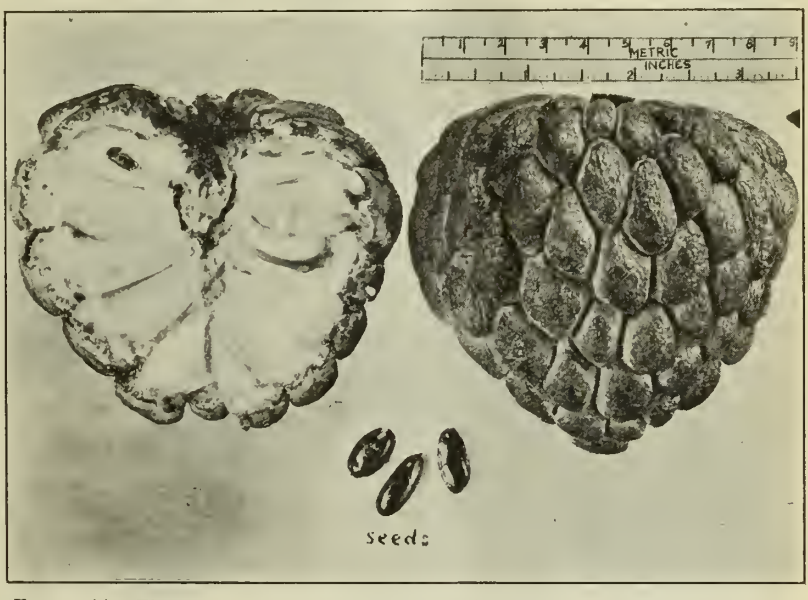

FIGURE 14.—The sugar-apple (*Annona squamosa*). This fruit is suitable for the lower elevations in Hawaii

MISCELLANEOUS NOTES

A number of fruit and nut plants were under investigation during the year. Attention was centered on those of greatest importance to the Territory, including the avocado, banana, breadfruit, citrus, coconut, date, grape, litchi,, Macadamia nut, mango, mountain apple, mulberry, papaya, poha, pineapple, strawberry, and tomato. Results of experiments with practically all these plants have been discussed at some length in former reports of the station, and the general habits, culture, and uses of the avocado, banana, citrus, litchi (fig. 13), Macadamia nut, mango, and papaya have been discussed in bulletins of the station.

Considerable attention has been given to certain fruit and nut plants of promise which as yet have not been grown to any great extent commercially in Hawaii. Interest in them is increasing. These plants include the soursop (*Annona muricata*), custard-apple (*A. reticulata*), ilama (*A. diversifolia*), sugar-apple (*A. squamosa*) (fig. 14), cherimoya (*A. cherimola*), cashew nut (*Anacardium occi-*

dentale), mangosteen (*Garcinia mangostana*), lanzon (*Lansium domesticum*), mabolo (*Diospyros discolor*), granadilla (*Passiflora quadrangularis*), the fragrant passion fruit (*P. alata*) (fig. 15),

FIGURE 15.—*Passiflora alata*. A very excellent edible fruit

waterlemon (*P. laurifolia*), purple-fruited waterlemon (*P. edulis*), and the large waterlemon (*P. ligularis*).

Propagating material of 77 species of fruit plants, either new to the Hawaiian Islands or rarely cultivated there, was obtained

during the year, and in most instances is being experimentally developed. The following are the more important of the plants under trial:

Akala berry (*Rubus hawaiiensis*). An unusual fruit, large, oblong, on long fruitstalk. Plant (No. 5452 [4]) received from Greenwell ranch, west slopes of Mauna Loa, Hawaii.

Bigaraldin (*Citrus* sp.). Two plants (No. 5504), representing a cross between sour orange and *Citrus mitis*, and grafted on a stock of citremon. Received from the Bureau of Plant Industry, United States Department of Agriculture.

Binukao (*Garcinia* sp.). Probably *Binuaco* sp. A small tree (No. 5458) with an edible, acid fruit.

Biribá (*Rollinia deliciosa*). An annonaceous fruit plant (No. 5456) from the Philippines. Native of northern Brazil and Guiana. The fruit, which is excellent, resembles the custard-apple in appearance.

Blueberry (*Vaccinium myrtilloides*). Three plants (No. 5469) received from the Bureau of Plant Industry, United States Department of Agriculture.

Breadfruit (*Artocarpus incisa*). The variety Kuru Peka (No. 5446) from Rarotonga. The variety Kauhina (No. 5471) the rooted cuttings of which came from Papeete, Tahiti. One root cutting (No. 5472) from Papeete, Tahiti. The variety Kuahe (No. 5473) two root cuttings of which came from Tahiti, South Seas. Two root cuttings (No. 5474) from Tahiti. The variety Ula Maopo (No. 5491) from Tahiti.

Bulso (*Gnetum indicum*). A large, woody vine (No. 5448), the seeds of which in the Philippines are used as nuts.

Canarium insulare. A nut-bearing tree (No. 5450) of unusual variety from Rarotonga, Cook Islands, South Seas.

Cashew nut (*Anacardium occidentale*). Two seedling trees (No. 5461) from a local nursery. The tree is of economic value for its edible fruit and nut.

Chocolate tree (*Theobroma cacao*). Trees (No. 5445) producing cocoa and chocolate from Rarotonga, South Sea Islands. One hundred and twenty-five seeds (No. 5492) from Papeete, Tahiti.

Citrus sp. Hybrid (No. 5509) resulting from crossing King orange and grapefruit and grafted on a citremon (*Citrus trifoliata*×lemon).

Coffee (*Coffea arabica*). A Hawaiian type (No. 5497) 16 seedlings of which were received from Molokai, Hawaiian Islands.

Dalinsi (*Terminalia edulis*). Used as a preserve fruit in the Philippines, whence it (No. 5442) came.

Dauag (*Capparis micracantha*). A shrub (No. 5457) producing bright-red, edible fruit. From the Philippines.

Duhat (*Eugenia cumini*). An ornamental fruit tree (No. 5444) from the Philippines.

Garcinia binucao. Tree seeds (No. 5498) from the Philippines.

Guava berry (*Eugenia lineata*). A golden-yellow variety (No. 5475) and a dark-red variety (No. 5476) from the Bureau of Plant Industry, United States Department of Agriculture.

Hibiscus spp. Seeds (No. 5486) from the Philippines.

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[4] Number under which plants were received at the station.

Kapok (*Ceiba acuminata*). A tree (No. 5460) of economic importance the seeds of which came from the University of Hawaii, Honolulu.

Kubili (*Cubilia blancoi*). Seeds (No. 5495) from the Philippines. The seeds are edible.

Lamio (*Dracontomelum edule*). A fruit tree (No. 5447) from the Philippines.

Lemon (*Citrus limonia*). A red variety (No. 5477), 56 seeds of which came from the Fiji Islands, South Seas.

Libato (*Basella rubra*). A trailing vine (No. 5459) the leaves of which are cooked and eaten in the Philippines like spinach.

Macadamia nut (*Macadamia ternifolia*). Six large nuts (No. 5481) from Hoaeae ranch, Oahu. Several nuts of a thin-shelled variety (No. 5482) from Hoaeae ranch, Oahu.

Oroxylum indicum. Eighteen seeds received of a tall tree (No. 5516) of economic importance.

Papaya (*Carica papaya*). Seeds (No. 5454) received of a good individual fruit grown in Papeete, Tahiti.

Parkia timoriana. Five seeds (No. 5515) received from the Philippines.

Passiflora sp. Seed (No. 5478) received from the Fiji Islands.

Perunkila (*Carissa* sp.). Used as a jam fruit in the Philippines whence it (No. 5443) came.

Pia or arrowroot (*Tacca pinnatifida*). Tubers (No. 5493) received from a grower on the island of Hawaii.

Pomelo (*Citrus grandis*). A sweet fruit (No. 5512) obtained from Chock Chin of Hanalei, Kauai.

Raspberry (*Rubus* spp.) Sixteen plants of the Lloyd George variety (No. 5463), 15 plants of the Cuthbert variety (No. 5464), 15 plants of the Herbert variety (No. 5465), 15 plants of the Latham variety (No. 5466), 15 plants of the Seneca variety (No. 5467), and 15 plants of the Ranere variety (No. 5468), all from the New York State Agricultural Experiment Station, Geneva, N. Y.

Santol (*Sandoricum koetjape*). An Indian fruit tree (No. 5451) from the Philippines.

Sapucaia nut (*Lecythis sabucaja*). Two seedling trees (No. 5462) from a local nursery. This species is valuable for its rich edible nut. It is a native of tropical South America. Fifty seeds (No. 5484) from the Bureau of Plant Industry, United States Department of Agriculture.

Siamelo (*Citrus* sp.). A hybrid (No. 5505) resulting from crossing King orange and grapefruit and grafted on a citremon (*Citrus trifoliata*×lemon).

Siamese pummelo (*Citrus* sp.). Variety Kao Panne (No. 5500). Variety Kao Panne (No. 5501). Variety Kao Phuang (No. 5502). One rooted cutting (No. 5503). All from the United States Department of Agriculture.

Sugar-apple (*Annona squamosa*). Fifty seeds (No. 5490) from local growers.

Solanum sp. Package of seeds (No. 5483) from Java via the Philippines.

Tangelo (*Citrus* sp.) A hybrid plant (No. 5506) received resulting from a cross between a tangerine and a grapefruit and grafted

on sapodia (sour pomelo×sour orange). One tangelo plant (No. 5507) received. Tangelolo (No. 5508), a hybrid resulting from crossing tangelo and grapefruit. Two plants received. All from the Bureau of Plant Industry, United States Department of Agriculture.

Terminalia sp. An ornamental (No. 5449) with an edible nut from Rarotonga, Cook Islands, South Seas.

Thunbergia sp. This species (No. 5499) from the Bureau of Agriculture, Philippines.

Tithonia speciosa. Seeds (No. 5485) from the Philippines.

REPORT OF THE POULTRY HUSBANDRY DIVISION

By C. M. Bice

The university farm maintains a flock of approximately 2,000 chickens of standard breeds for instructional purposes and for use in

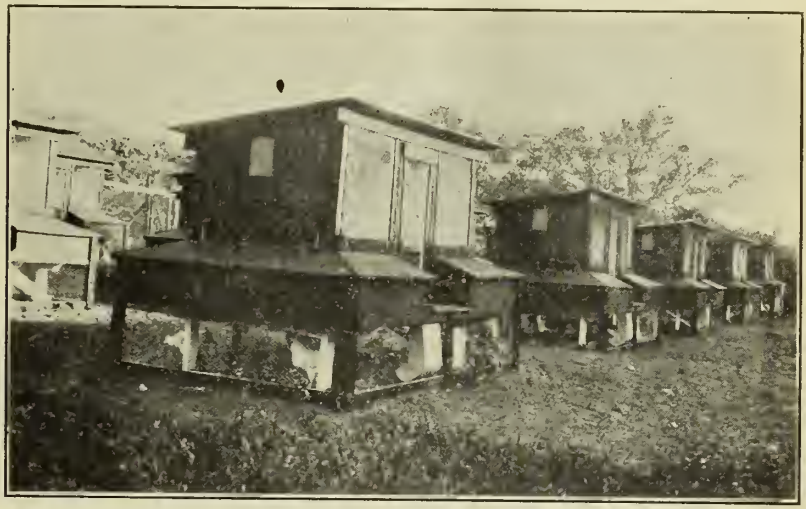

Figure 16.—Poultry houses, University of Hawaii farm

projects carried on by the experiment station. Five of these projects were under way during the year. (Fig. 16.)

SOREHEAD (FOWL POX) CONTROL IN BABY CHICKS

Sorehead (fowl pox) is probably the most destructive of any of the local poultry diseases. The mortality of chicks from fowl pox in Hawaii ranges from approximately 25 to 45 per cent of the total number of chicks hatched yearly. The disease is widespread throughout the Territory, and appears each year. Fowl pox has been identified as Epithelioma contagiosum by Dr. O. N. Allen, of the University of Hawaii. An experiment was begun to determine how the disease is transmitted to baby chicks with the hope of devising practical methods for its control. One thousand baby chicks one day old were divided into five equal groups and kept under different conditions of housing and yarding. Five brooder houses and runs

were used in the experiment, three of which were entirely mosquito-proof. The chicks were confined in these houses until 13 weeks of age, when they were transferred to the laying house or to small colony houses for further study. One of these small colony houses was made mosquito-proof but had a run which was not mosquito-proof; the other house and its run were not mosquito-proof. Twenty-five chicks were placed in each of these houses. Twenty-five chicks were placed in another small colony house and given access to the ground. In every instance except the latter the chickens were kept off the ground by means of a ½-inch mesh hardware wire floor or a concrete floor. Records were kept of the number of birds in each house, the number of cases of sorehead, and the number of deaths from the disease. Characteristic sorehead lesions appear 7 days after the mosquito has fed on the chick. The findings appear to confirm those obtained in preliminary experiments along this line and previously reported, viz, that sorehead is transmitted to baby chicks by mosquitoes and may be prevented by screening the runs and houses (*1*).

SEX DETERMINATION IN DAY-OLD PUREBRED CHICKS

Attempts were made to find in day-old purebred chicks some definite sex-linked character, which is always present and readily observable, other than by extremely close scrutiny, preferably with a hand lens, of the internal organs. Most of the studies dealt with the tonal characters of the "peep" uttered by the chick when it was picked up. Some of the tests showed as high as 68 per cent correct determinations. However, the use of any method giving less than an average of 90 per cent is not considered to be commercially feasible.

FEEDING

HAWAII MINERALS FOR POULTRY

Experiments were undertaken to determine the comparative efficiency of Hawaii minerals with oyster shells and with poultry bone and the like for egg production, fertility, hatchability, and livability of chick. Two hundred and seventy Single Comb White Leghorn pullets were divided into nine equal groups. Each group was confined in a house having a run. The houses were of the same size and similarly constructed. The mash and the scratch grain were the same for each group, except in pens where the chicks received mineral supplement in addition to the mash. The mineral supplements fed included oyster shells in hoppers, raw rock phosphate (8 pounds per 100 pounds of mash), coral sand (8 pounds per 100 pounds of mash), crushed reef coral in hoppers, oyster shells and poultry bone in hoppers, raw rock phosphate (6 pounds per 100 pounds of mash) and poultry bone in hoppers, coral sand (6 pounds per 100 pounds of mash) and poultry bone in hoppers, and crushed reef coral and poultry bone in hoppers. A check lot received no minerals. Records were kept of egg production, fertility, hatchability, mortality, labor expended, and feed consumption.

CANE MOLASSES FOR BABY CHICKS AND FOR LAYING HENS

Three groups each of 189 chicks were fed a mash and scratch ration with varying percentages of molasses as a supplement, and a

check group of 189 chicks received no molasses. Of the first three groups, one received 5 per cent of molasses, the second 7 per cent, and the third 10 per cent. The pullets from each of these groups were fed the same percentages of molasses throughout the first laying year. Records were kept of cost of feed, growth, production, and mortality of fowl, and of the labor expended.

ALL-MASH METHOD OF FEEDING LAYING HENS

An experiment was begun comparing the all-mash method with the mash and scratch method of feeding laying hens. Sixty-six Single Comb White Leghorn pullets on free range were fed a commercial all-mash mixture, and an equal number of Single Comb White Leghorns on free range were fed a commercial mash and scratch mixture. All other management was the same for the two groups. Records were kept on the cost of feed, growth, production, fertility, hatchability, mortality, and of the labor expended. The results obtained were not conclusive, and the experiment will be repeated.

REPORT OF THE SOIL PHYSICS DIVISION

By H. A. Wadsworth

CAPILLARY PHENOMENA IN COLLOIDAL SOILS

During the year a study was made of the factors affecting the rate and height of capillary rise of water through colloidal soils supported over a free-water table. Part of the first year's work, reported here in abstract, dealt with a study of principles. An analogy is often drawn between the capillary rise of water in soils and a similar rise in glass tubes of small diameter. A careful search of the literature of physics failed to disclose studies of the rates of rise of liquids through minute glass tubes. Such studies were therefore undertaken. The equations used in these studies were as follows: $R=K\ (1-e^{-cT})$. Where K and c are constants R=rise in cubic millimeters after T seconds and e=base of natural logarithms.

It is evident that R increases rapidly with T until a critical value for T is reached, beyond which R shows no further increase. In other words, R approaches an asymptotic value. The action is much more complex when carefully screened soils are used. The initial phase of the rise is similar to the form indicated above, but no asymptotic value is reached, the rise continuing long after the term e^{-cT} becomes zero. Consequently, another factor must be taken into account when clean inert sands are used. One hundred and twenty observations were made with five carefully graded sand sizes and a form of expression developed which fits the observed points with surprising precision. The formula may be expressed thus: $R=K\ (1-e^{-cT})T^n$. This formula may be used when the notation is as in the first formula given above, and n equals the natural tangent of the slope caused by plotting logarithmic rise against logarithmic time for values of T larger than that for which e^{-cT} equals zero. The fact that the second phase of the process makes a straight line on logarithmic paper is not an original finding. However, no

attempt has been discovered to analyze the initial phase. The curves from the many observations indicated above are now being evaluated in such a way as to permit identification of significant differences between the several sizes of sands used. Observations at hand indicate that the value of n is independent of grain size. K seems to increase with a reduction in average grain size, whereas c decreases in the same sense. This analysis is complicated by the fact that average grain size alone is not a sufficient criterion for analysis. The range of sizes between the arbitrary limits and the distribution of sizes between them seem to be of great importance. The most important conclusion reached thus far is that capillary rise of water through sands is not a simple, continuous process, but is the result of two actions, each of which follows a different law. The exact nature of these laws has not been determined. Studies with soils emphasize this discontinuity. Here the initial curve seems to degenerate into an initial straight line when plotted logarithmically and a rather sharp point of intersection is provided. This break at once suggests McLaughlin's hump. No satisfactory correlation between these two characteristics has been noted. In fact, many careful observations on the distribution of moisture in columns of local soil fail to disclose an isolated zone of maximum water content, although the moisture distribution is by no means continuous.

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U. S. GOVERNMENT PRINTING OFFICE: 1931